Wilson Bull., 95(3), 1983, pp. 384–403

JAMAICA BAY STUDIES: IV. ABIOTIC FACTORS AFFECTING ABUNDANCE OF BRANT AND CANADA GEESE ON AN EAST COAST ESTUARY

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Most Brant (*Branta bernicla*) and Canada Geese (*B. canadensis*) breed in northern Canada, although Canada Geese also nest in some areas of the United States. During the breeding season Brant and other geese are terrestrial grazers. In the non-breeding season Canada Geese continue to eat terrestrial plants and seeds. However, Brant switch to feeding on submerged aquatic plants (Weller 1975), although lack of food in marine bays and estuaries can force them to rely on salt marsh vegetation (R. Creedan, pers. comm.). In this paper we examine the spatial, temporal (time of day and year), tidal, and weather-related (wind, temperature, precipitation, cloud cover) factors influencing the abundance and local distribution of Brant and Canada Geese at Jamaica Bay Wildlife Refuge. The refuge on Long Island, New York is a 3600-ha coastal estuary containing a variety of tidal mudflats and marshes, and two large man-made freshwater ponds. This variety of habitats provides sufficient diversity for habitat selection. The results reported herein are part of an extensive study of how waterbirds use Jamaica Bay Wildlife Refuge, and results relating to other groups of birds are discussed elsewhere (Burger 1982, 1983a,b).

STUDY AREA AND METHODS

Jamaica Bay Refuge, part of the Gateway National Recreational Area (National Park Service), is located on the south shore of western Long Island, New York. The bay, a tidal lagoon containing many salt marsh islands, is shallow (less than 3 m deep at low tide) except for dredged channels. During late summer and fall the tidal fluctuation in Jamaica Bay averages 1.4 m (range = 0.9–2.13 m). The area of mudflats exposed at low tide varies with the lunar cycle and seasons. There are approximately 374 ha of low salt marsh (containing primarily cordgrass [*Spartina alterniflora*]) submerged at mean high tide, and exposed at mean low tide. High salt marsh (213 ha, mostly salt hay [*S. patens*]) occurs in well drained areas above the mean high tide limit.

Surrounded by the bay are two freshwater impoundments that were created by the deposition of spoil in 1953 (West Pond—17 ha, East Pond—39 ha). The National Park Service personnel lower the water levels in West Pond on 1 April (it gradually fills up by early summer) and they lower water levels in East Pond after 1 July each year. East Pond is completely surrounded by phragmites (*Phragmites communis*), although West Pond is bordered by this plant on only one side.

The refuge is bordered by J. F. Kennedy International Airport, residential communities, several active sanitary landfills, and expressways. Human disturbance is generally minimal in most areas of the bay (Burger 1981). A path around West Pond provides easy access, although joggers (present nearly daily in the summer) flushed the birds from the edge of the pond. Few people ever visited East Pond, and a trail had to be hacked through the phragmites to allow censusing.

For purposes of this study, Jamaica Bay Wildlife Refuge was divided into three census areas: tidal bay, East Pond, and West Pond. Brant and Canada Geese were censused during daylight from 31 May 1978–31 May 1979. The two ponds were censused 4 days per week every other week (8 h/day), and on two days on the alternating weeks. The ponds were censused twice daily (at low and high tide). Birds in West Pond were censused at prescribed stops (which allowed coverage of the entire pond), while those in East Pond were censused at stops determined by flock location. During each census the locations of all birds were plotted on maps of the ponds, and all areas of each pond were censused.

The tidal bay, visited 2 days every other week, was censused by following a route around its perimeter which included 17 stops where birds were counted. At each stop a census area was mapped. The 17 maps covered all visible areas of the bay with no overlap, although it was possible to see many areas from several census stops. On each census day, the locations of all birds were plotted on the 17 maps.

During each census we also recorded environmental variables, grouped into three categories: temporal, tidal, and weather. Temporal variables include date and time of day; tidal variables include tide cycle, tide direction, and tide height; and weather variables include wind velocity, wind direction, cloud cover, precipitation, and temperature. Although the tidal variables are all related (tide time, tide height), they generally were not highly correlated. Variables were defined and measured as follows: date—day of the year; time—time of the census on a 24 h clock; tide cycle—number of h before (−) or after (+) low tide; tide height—a relative value of the water level of the bays derived from tide tables; tide direction—rising (+) or falling (−) tide; wind direction—direction of the wind (N, NE, E, SE, W, NW); wind velocity—speed of wind recorded at Kennedy Airport on the edge of Jamaica Bay; cloud cover—estimated at each census location, recorded as a percent; precipitation—scored from 0 (none)–9 (heavy rain or snow); temperature—recorded from a hand carried thermometer and corrected against readings from Kennedy Airport.

Wind velocity was measured several times throughout each day, and the average windspeed was used for analysis. For the purposes of presentation we divided wind velocity into categories. However, gusts of much higher velocity occurred in each category as follows: 0–3 mph (gusts up to 20), 3–6 (up to 40), >6 (over 40 gusts).

To assess the importance of these variables to our dependent measures (number of flocks, number of individuals) we used stepwise multiple regression procedures to determine the variables that should be entered in the model (including interactions [Barr et al. 1976]). Most independent variables were ordinal, and could be analyzed without transformations. Since wind direction was not ordinal, a new variable was created which compared the dependent measures at each wind direction against all other wind directions; examining each wind direction in turn. If any wind direction was significant it was entered into the model. The stepwise procedure first selects the variable that contributes the most to the coefficient of determination (R^2) and then selects the second variable that gives the greatest increase in R^2. This procedure is continued until all variables that have not been included in the model are not statistically significant. Thus, if variables were highly correlated only one variable (the one giving the highest R^2) would be added to the model. This model selection procedure determines the best model, gives R^2 values and levels of significance for the model, as well as giving the F values and levels of significance for each of the contributing variables. In this paper we present the best models for each dependent variable and levels of significance

TABLE 1

OCCURRENCE AND MEAN (± SD) FLOCK SIZE OF BRANT AND CANADA GEESE AT JAMAICA BAY WILDLIFE REFUGE

	N[a]	Bay	West Pond	East Pond
Brant—No. individuals	193,372	68%	39%	2%
—flock size	162	1962 ± 132.1	92.1 ± 63.1	85.1 ± 46.1
Canada Goose—No. individuals	9038	11%	64%	25%
—flock size	138	49.6 ± 36.1	110.6 ± 52.1	19.2 ± 9.2

[a] Represent relative numbers, since any given flock might remain at Jamaica Bay Wildlife Refuge for several weeks in the winter.

for the independent variables. In general, the independent variable giving the highest R^2 has the lowest probability, and enters the model first. Thus, the relative value of the probability levels are indicative of the contribution made by each variable (i.e., a variable significant at $P \leq 0.0001$ generally contributes more to the observed variation in the dependent variable than one that is significant at $P \leq 0.01$). All statistical procedures were performed on log transformed data ($\log_e[x + 1]$). On graphs we plot logs for the number of birds and number of flocks. We also used χ^2 tests to distinguish differences among means of different samples.

For most analyses we grouped data by location since each area was sampled separately. For convenience we often present the data in graphs showing each location so that comparisons can be made.

RESULTS

During the study Brant accounted for 65% of the over 200,000+ Brant and Canada Geese observed at Jamaica Bay Wildlife Refuge (Table 1). Brant used primarily the tidal bay, whereas Canada Geese used mostly West Pond. Brant formed the largest flocks, and the largest flocks were on the tidal bay (Table 1).

Factors affecting the numbers of Canada Geese and Brant.—The model for number of flocks of Canada Geese accounted for between 37% and 78% of the variability by temporal (only on West Pond), and weather variables (all areas, Table 2). Weather-related variables that significantly influenced the number of flocks were wind velocity, wind direction, temperature, and cloud cover. The models for the number of individual Canada Geese explained between 54% and 76% of the variability by date (except on the bay) and weather variables such as wind velocity and direction (bay, West Pond), temperature (bay, East Pond) and cloud cover (bay, see Table 2). In summary, variations in number and distribution of Canada Geese were accounted for by temporal and weather-related, but not tidal variables.

TABLE 2

ENVIRONMENTAL VARIABLES INFLUENCING THE NUMBER OF INDIVIDUALS AND FLOCKS OF CANADA GEESE ON JAMAICA BAY WILDLIFE REFUGE

	Bay		East Pond		West Pond	
	Flocks	Individuals	Flocks	Individuals	Flocks	Individuals
Model						
	78					
R^2	10.87	72	65	54	37	56
F	0.0004	11.95	11.01	5.70	6.33	16.08
P		0.0004	0.0001	0.0005	0.0001	0.0001
df	2,14	3,13	5,30	5,30	4,66	3,67
Variables						
Temporal						
Date	—	—	—	0.001	0.0001	0.0001
Date and time	—	—	—	0.005	—	—
Tidal						
Weather						
Wind direction	—	—	0.0008	0.03	—	—
Wind velocity	0.002	0.0007	0.07	—	0.05	0.02
Wind direction and velocity	—	—	—	—	0.05	0.01
Temperature	0.006	0.001	0.0001	0.002	—	—
Cloud cover	—	0.002	0.005	—	—	—
Interactions						
Temperature and wind velocity	—	—	—	—	—	—
Tide and wind direction	—	—	0.02	0.02	0.05	—

The models for the number of flocks of Brant explained between 24% and 77% of the variability by day and time (West Pond only), tidal, and weather-related variables (all areas, Table 3). The weather-related variables which entered the models for the number of Brant flocks were wind velocity and direction (both ponds), temperature (bay, East Pond), and cloud cover (bay, East Pond). The model for variability in the number of individual Brant explained between 39% and 79% of the variation by temporal (not on the bay), tidal (bay, East Pond), and weather variables (all areas, Table 3). Wind direction and velocity (all areas), temperature (bay, West Pond), and cloud cover (bay, East Pond) significantly influenced distribution and abundance. Thus, for both species, numbers were influenced by temporal and weather-related variables, but only Brant were

TABLE 3

ENVIRONMENTAL VARIABLES INFLUENCING THE NUMBERS OF INDIVIDUALS AND FLOCKS OF BRANT ON JAMAICA BAY WILDLIFE REFUGE

	Bay		East Pond		West Pond	
	Flocks	Individuals	Flocks	Individuals	Flocks	Individuals
Model						
R^2	24	39	77	79	38	58
F	9.76	11.29	10.80	12.40	5.69	8.62
P	0.0001	0.0001	0.0001	0.0001	0.001	0.0001
df	3,91	4,88	5,16	5,16	4,39	4,39
Variables						
Temporal						
Date	—	—	—	0.0001	—	—
Date and time	—	—	—	—	0.006	0.001
Tidal						
Tide cycle	0.002	0.005	—	—	—	—
Tide height	—	—	0.02	—	0.05	—
Weather						
Wind direction	—	—	—	0.004	0.03	0.04
Wind velocity and direction	—	—	0.02	—	0.01	0.01
Temperature	0.001	0.0001	0.008	—	—	0.01
Cloud cover	0.005	0.005	0.001	—	—	—
Interactions						
Tide and wind direction	—	—	—	0.003	—	—
Temperature and date	—	—	0.0001	—	—	—
Cloud and wind velocity	—	0.03	—	0.004	—	—

tidally-influenced. The effect of each class of variables will be discussed separately.

Temporal variables.—The number of flocks of Brant and Canada Geese varied throughout the year with most flocks of Brant on West Pond; and most flocks of Canada Geese on both ponds (Fig. 1). Peak concentrations of Canada Geese occurred from October–April (Fig. 2). The seasonal pattern in the numbers of Canada Geese shows an increase in late June and July in addition to the winter increase in population levels (Fig. 2). This influx may represent post-breeding dispersal from nearby nesting areas such as Brigantine National Wildlife Refuge (New Jersey). Most Brant were at Jamaica Bay from October–December, although Brant did

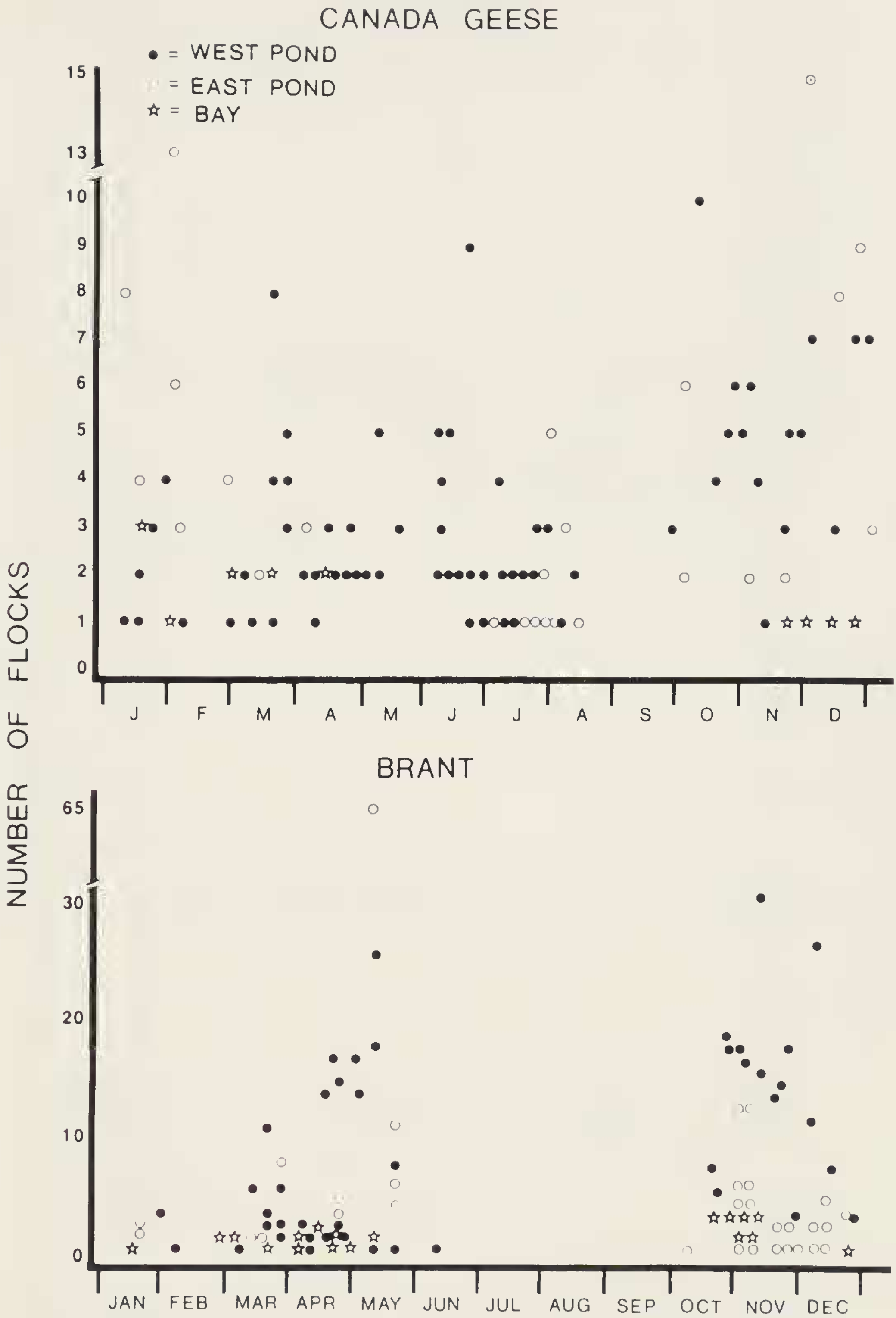

FIG. 1. Seasonal distribution of flocks of Brant and Canada Geese on the three census areas of Jamaica Bay Wildlife Refuge.

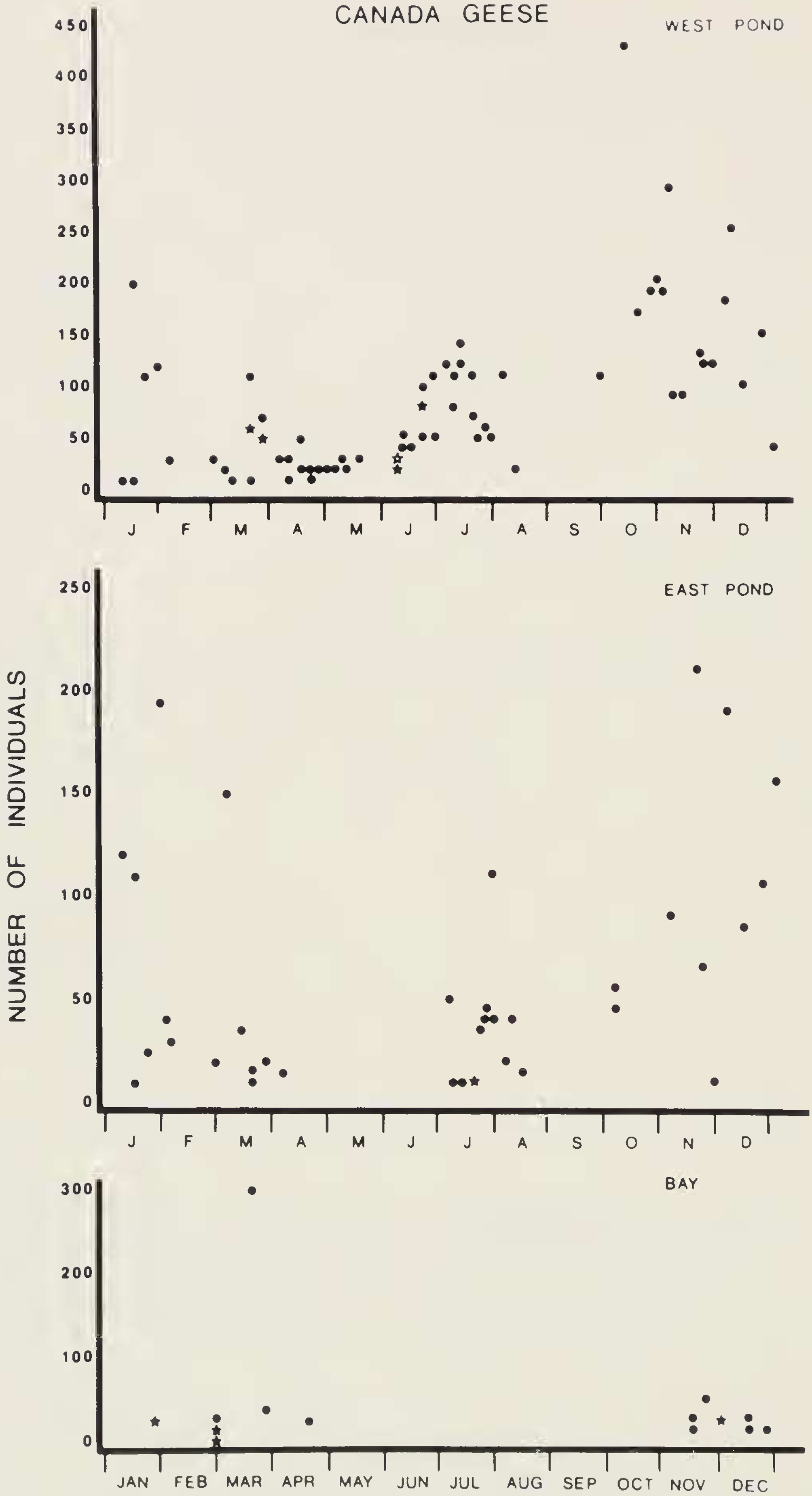

FIG. 2. Number of Canada Geese on Jamaica Bay as a function of month. Solid circle = 1, solid star = 2, open star = 3, and square = 4 observations.

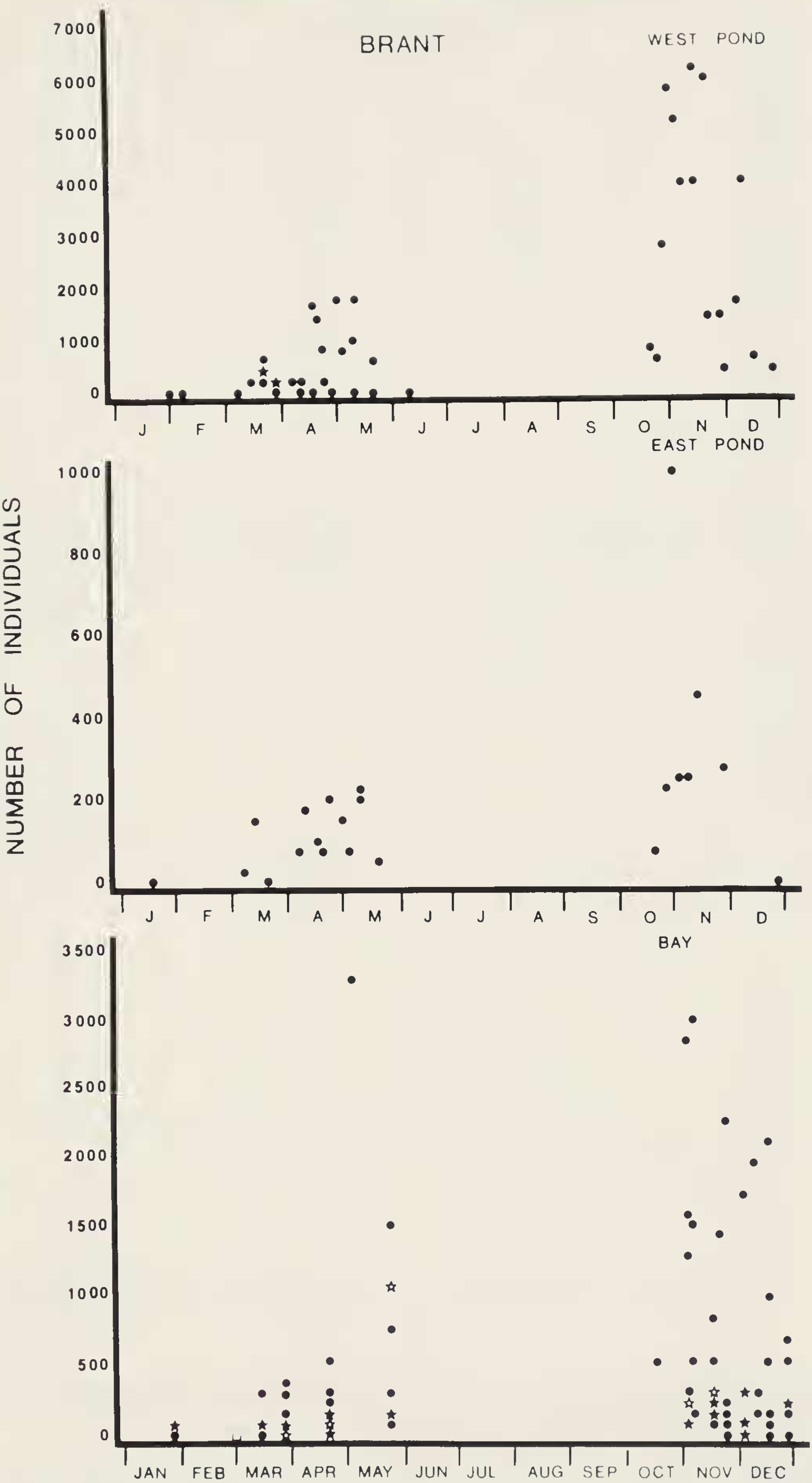

FIG. 3. Number of Brant on the census areas as a function of month; symbols the same as Fig. 2.

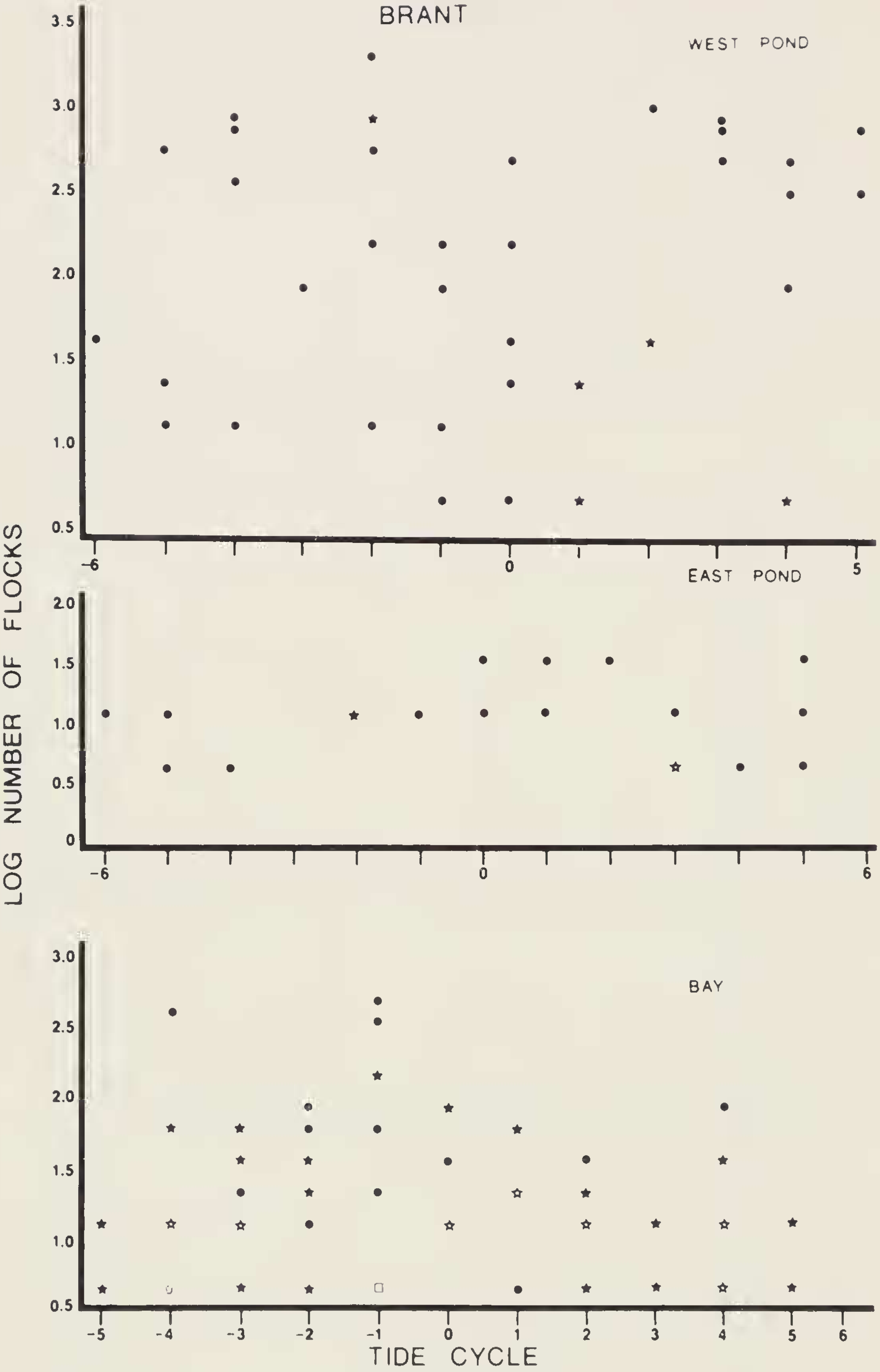

FIG. 4. Number of Brant flocks in the three census areas as a function of tide cycle. 0 = low tide; symbols the same as Fig. 2.

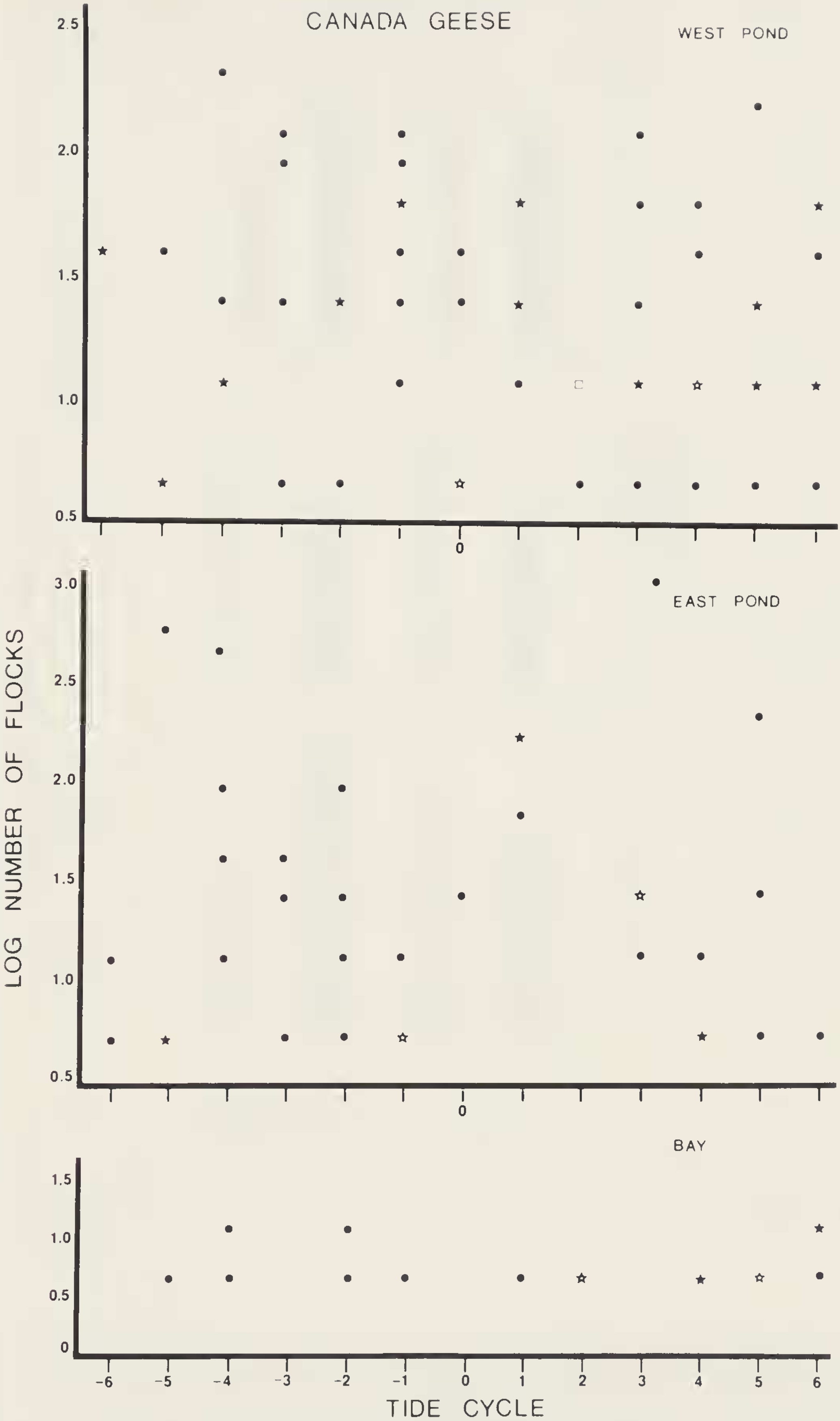

FIG. 5. Number of Canada Geese flocks in the three census areas as a function of tide cycle. 0 = low tide; symbols the same as Fig. 2.

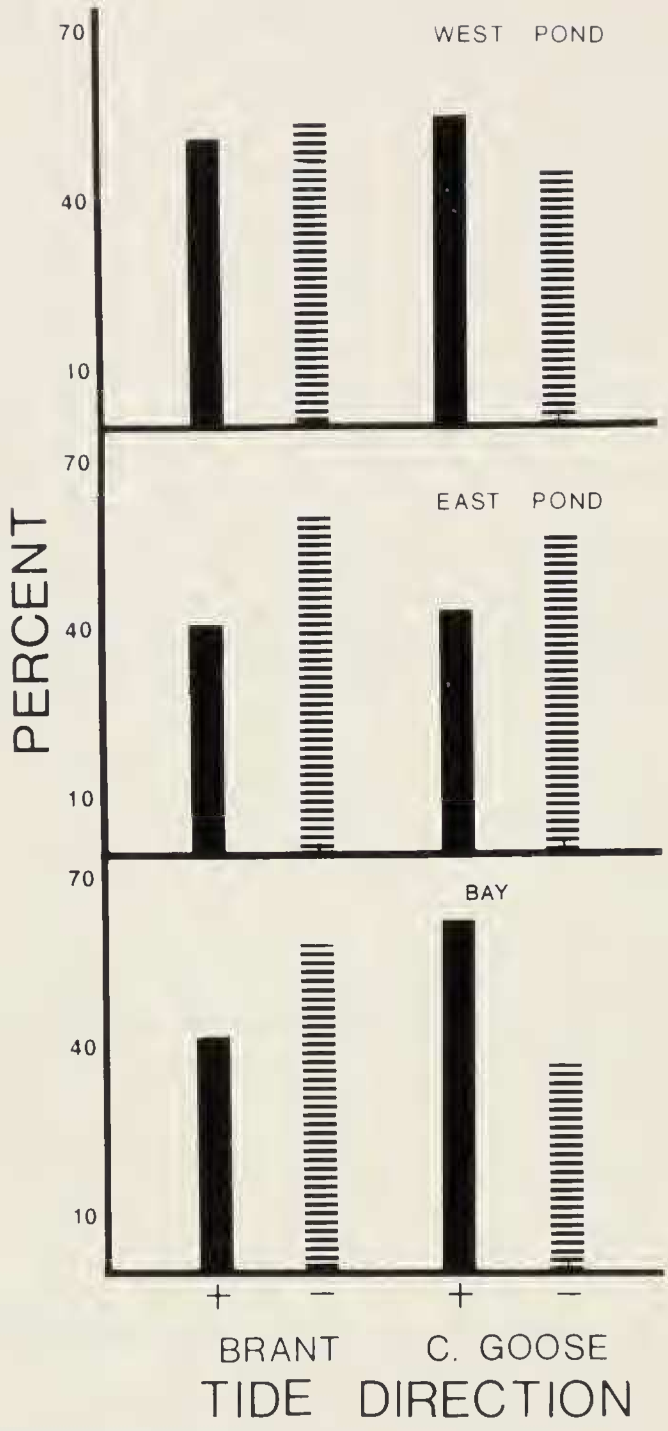

FIG. 6. Percent of Brant and Canada Geese flocks as a function of tide direction for each census area.

migrate through from March–May (Fig. 3). Generally the number of individual Brant per census (day) was less during spring migration.

Tidal influences.—Several tidal factors, such as tide cycle, tide height, and tide direction, could influence the abundance and local distribution of Brant and Canada Geese. Tidal factors influenced the number of flocks

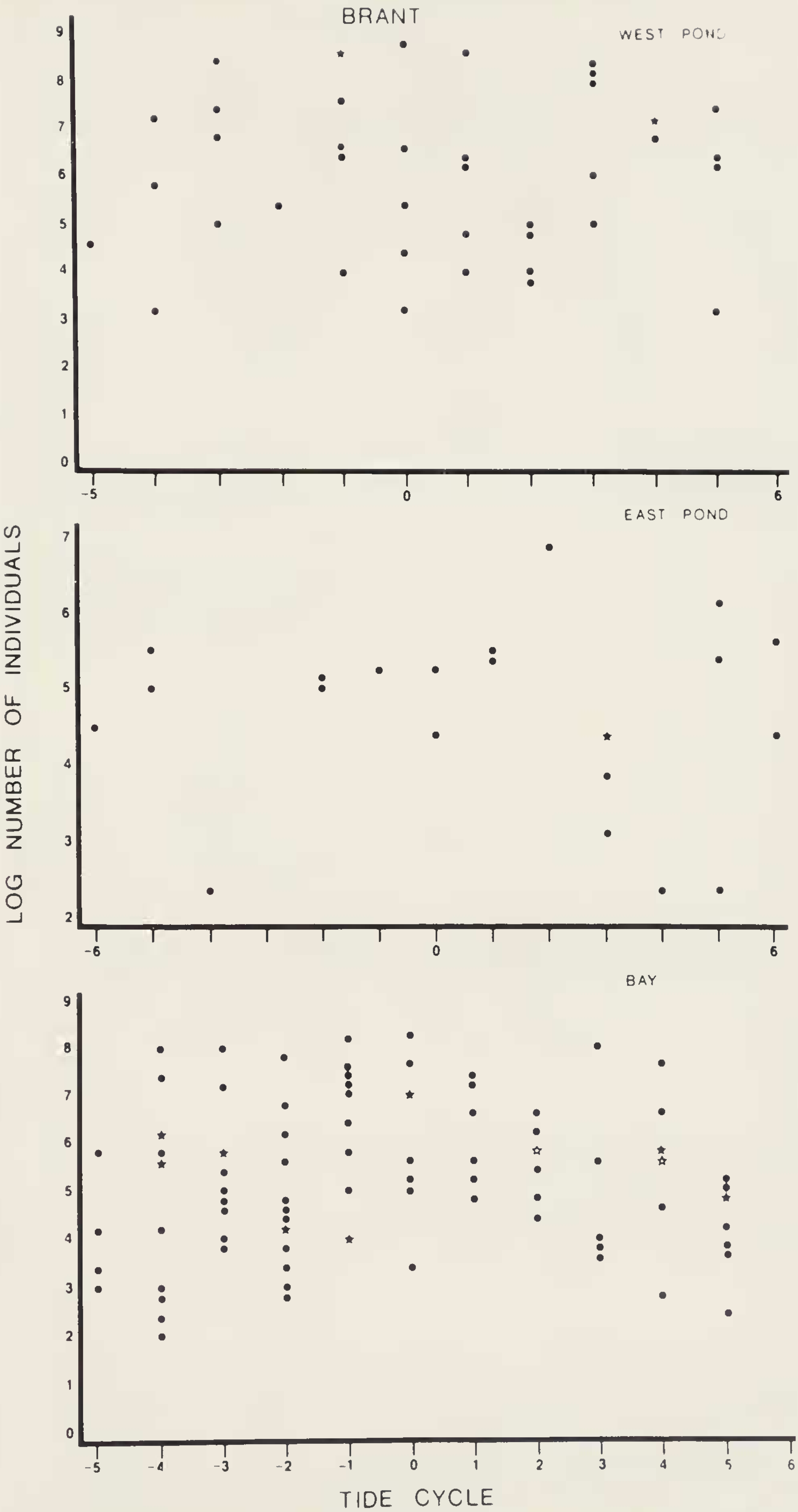

FIG. 7. Number of Brant in the three census areas as a function of tide cycle. 0 = low tide; symbols the same as Fig. 2.

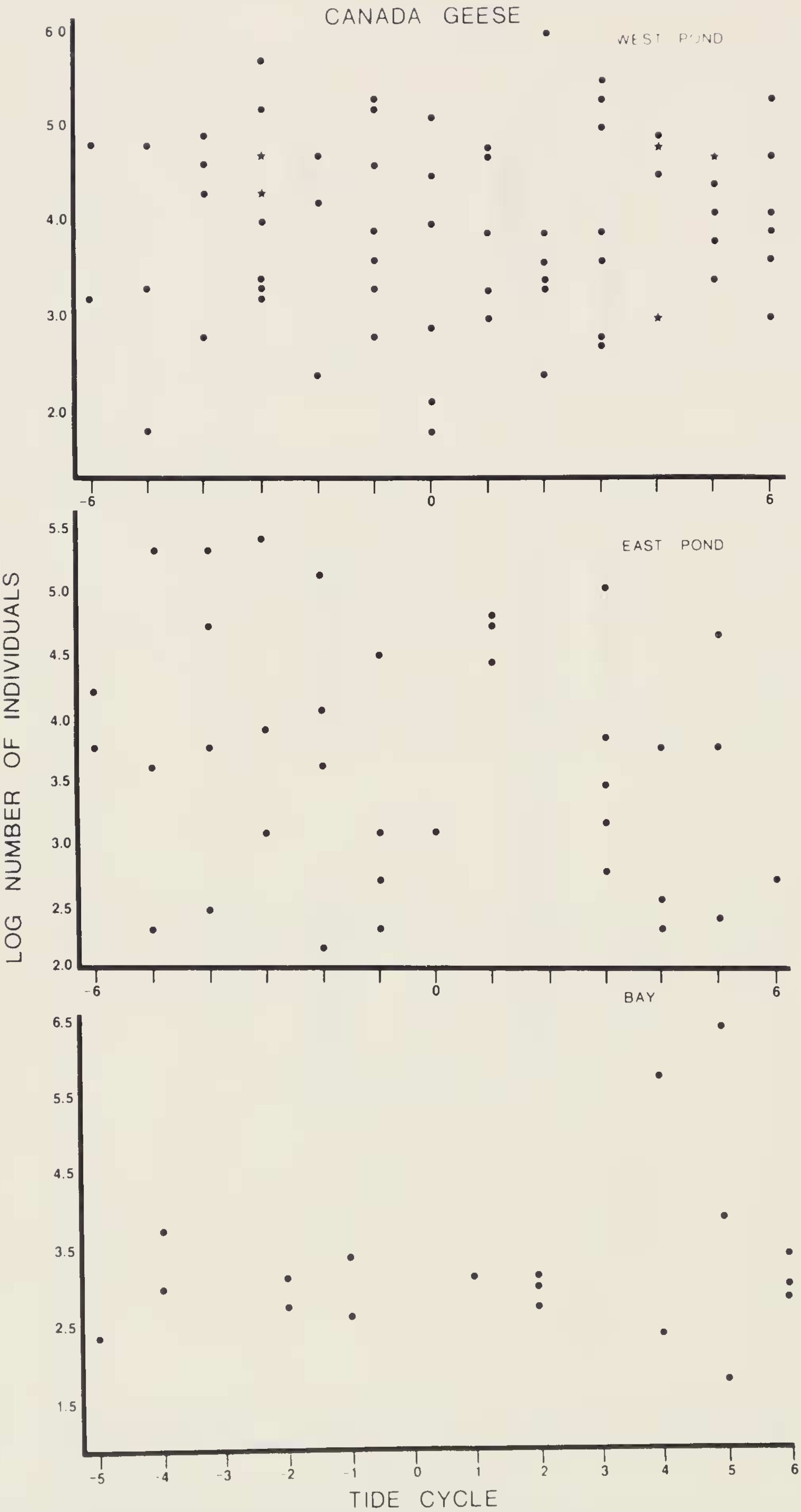

FIG. 8. Number of Canada Geese in the three census areas as a function of tide cycle. 0 = low tide; symbols the same as Fig. 2.

TABLE 4
COMPARISON OF THE NUMBER OF FLOCKS OF BRANT AND CANADA GEESE USING THE BAY, EAST POND, AND WEST POND

	Canada Geese			Brant		
	χ^2	df	*P*	χ^2	df	*P*
N	138			162		
Tide cycle[a]	1.52	4	NS[b]	4.89	4	NS
Tide direction[c]	2.68	2	NS	6.58	2	<0.05
Wind direction[d]	14.20	6	<0.05	22.38	6	<0.005
Wind velocity[e]	3.68	4	NS	9.48	4	<0.05
Temperature[f]	48.6	8	<0.0001	11.16	4	<0.05
Cloud conditions[g]	5.85	4	NS	5.98	4	NS

[a] Tide cycle divided into 2–6 h before low, 2 h before to 2 h after low tide, and 2–6 h after low tide.
[b] NS = not significant.
[c] Rising and falling tide.
[d] Four directions: NNE, ESE, SSW, and WNW.
[e] Divided into 0–3 mph, 3–6 mph, and >6 mph wind velocities.
[f] Divided into 10°C temperature blocks.
[g] Divided into 0%, 2–99%, and 100% cloud cover.

and individuals of Brant but not of Canada Geese (Tables 2 and 3). More flocks of Brant occurred on the bay on a falling tide and at low tide than on a rising tide, although the reverse pattern is evident for Canada Geese (Figs. 4–6). Most sightings of Canada Geese were on a rising tide on the bay and West Pond, and on a falling tide on East Pond (Fig. 6). Similarly, there were more Brant on the bay on a falling tide and at low tide than on a rising tide (Fig. 7) but tidel level apparently did not influence numbers of Canada Geese (Fig. 8). Tide height also affected Brant numbers. More Brant were present on the bay at low tide heights, and on the ponds at high tide heights.

In the above analysis we examined the effect of tidal factors within each census area (bay, East Pond, West Pond). Comparing the effect of tidal factors among census areas indicates significant differences in tide direction (but not tide cycle) for Brant, but not for Canada Geese (Fig. 6, Table 4). Brant used the bay and East Pond on rising tides, and used West Pond equally with respect to tides.

Weather factors.—Precipitation did not significantly affect the distribution or number for either species. Numbers of flocks and individuals of Canada Geese (all areas) and Brant (all areas except the number of flocks on the bay, refer to Tables 2 and 3) were affected by wind velocity and direction. Brant used the bay less on high winds (mean wind velocity of over 6 mph with gusts much higher) compared to other areas (Fig. 9).

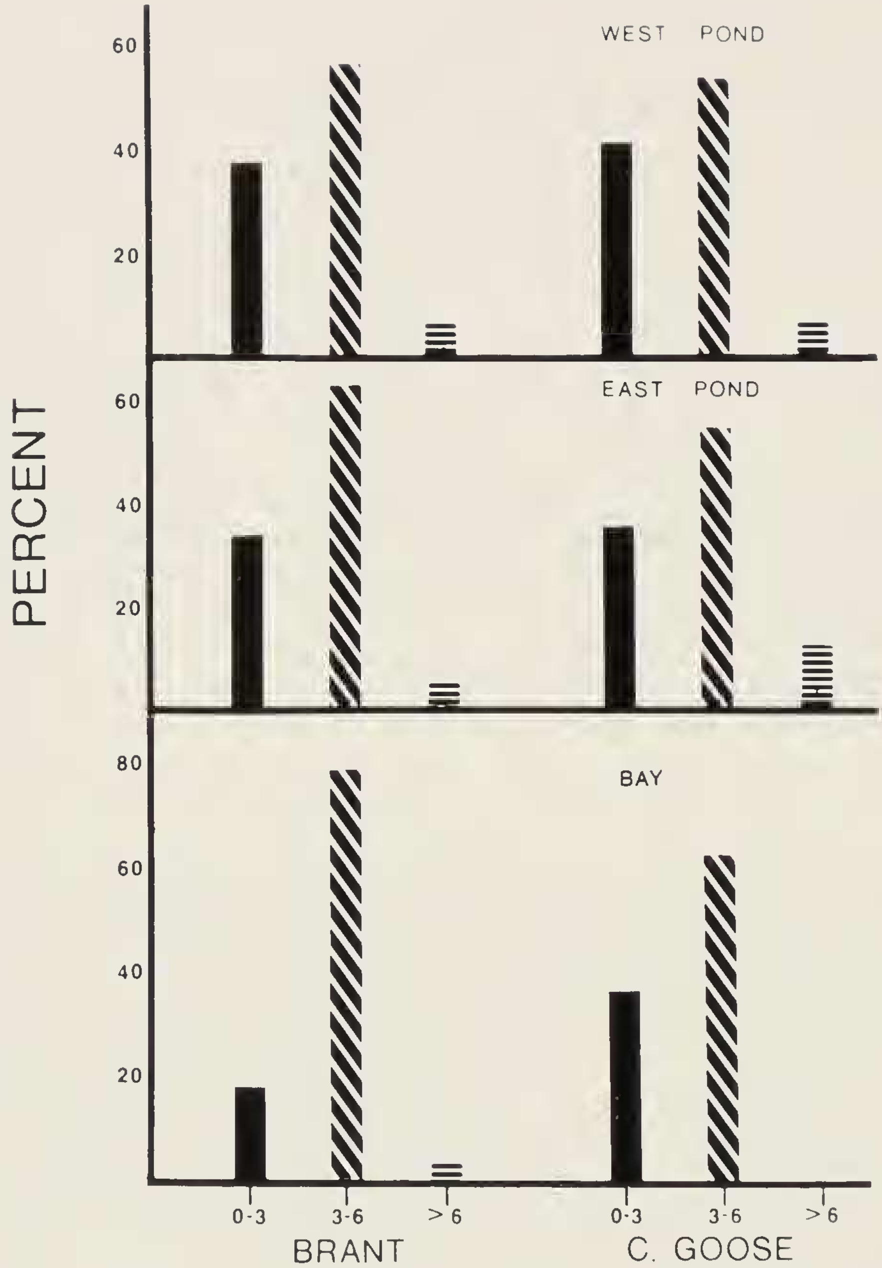

FIG. 9. Percent of Brant and Canada Geese present as a function of wind velocity on each census area. Data given in mph (as recorded); wind velocity given as mean velocities, but gusts could be much higher.

Significant differences existed in the use of each census area as a function of wind direction (Table 4): (1) Brant used the bay more during NNE and WNW winds than they used the ponds, and they used the ponds more during ESE and SSW winds; (2) Canada Geese used the bay mostly during WNW winds, and used the ponds when winds were from other directions; and (3) Canada Geese used the bay more during WNW winds than did Brant (Fig. 10).

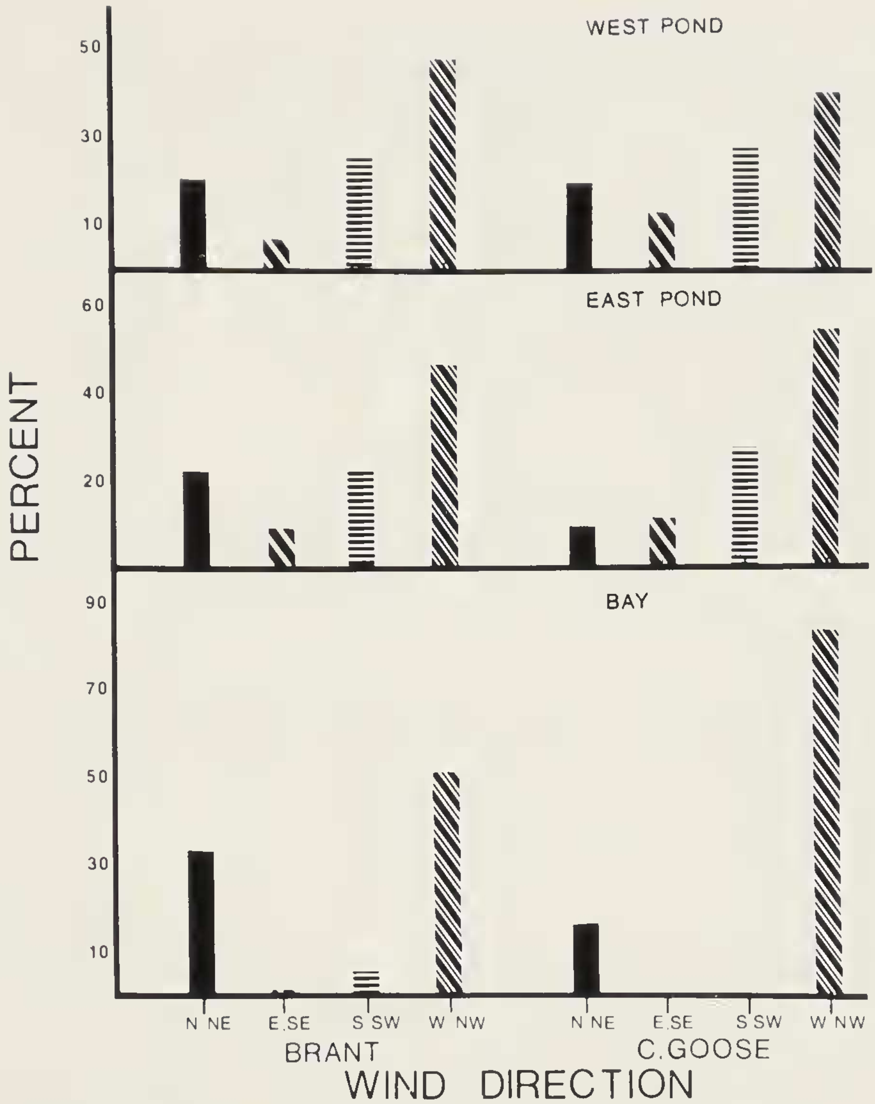

FIG. 10. Effect of wind direction on Brant and Canada Geese on the three census areas.

Since Canada Geese were present throughout the year, they encountered a wider range of temperatures than Brant (Table 5). Nonetheless, significant differences in habitat use occurred (Table 5). Brant used the bay more at lower temperatures than the ponds, and they used the two ponds similarly. Canada Geese used the bay at low temperatures, West Pond at intermediate temperatures, and East Pond at all temperatures including very high temperatures (Table 5).

Cloud cover influenced the numbers of flocks of Canada Geese on East Pond only, and of Brant on both ponds; and cloud cover influenced the number of Canada Geese on the bay, and the number of Brant on the bay and East Pond (Tables 2 and 3). For both species there were no differences

TABLE 5
PERCENT OF BRANT AND CANADA GEESE ON EACH CENSUS AREA AS A FUNCTION OF TEMPERATURE (°C)

	<−4°	−3°–+7°	+8°–+18°	+19°–+29°	>29°
Brant					
East Pond	0	21	58	21	0
West Pond	3	20	58	18	0
Bay	2	46	40	12	0
Canada Geese					
East Pond	12	30	12	14	32
West Pond	7	20	28	45	0
Bay	5	78	12	5	0

in how they used the census areas as a function of cloud cover (Table 4). For both species there were fewer flocks in lower cloud cover.

DISCUSSION

Habitat comparisons.—In this study Brant primarily used the tidal bay, and Canada Geese were most abundant on freshwater West Pond. Brant were usually found in rafts on the water, whereas Canada Geese frequently fed on shore near West Pond. Other researchers (Weller 1975, Fredrickson and Drobney 1979) report a similar pattern of foraging behavior and locations for these species during migration. Stewart (1962) and Daiber (1977) also noted that Canada Geese fed primarily on coastal marshes and fresh estuarine bay marshes in Maryland and Delaware.

Temporal effects.—Canada Geese occurred in the refuge throughout the year, whereas Brant were migrants and winter residents. The influx of Canada Geese in June and July indicates that the refuge is used as a post-breeding staging area for young of the year and adults. Presumably the post-breeding birds mostly used the freshwater ponds since the increase in usage occurred there (Fig. 3). Although post-breeding birds primarily used West Pond, they did use East Pond in July and August. This difference in usage reflects management practices: during the entire year there are grassy areas around West Pond which are suitable for foraging and loafing. However, East Pond is bordered by phragmites and there are loafing areas for the Canada Geese only when refuge personnel lower the water levels (1 July).

Time of day rarely influenced numbers, but there tended to be more birds on ponds late in the day. The ponds were frequently used as loafing and preening areas by flocks. In this study, tidal and weather factors (see below) were more important than time of day as contributors to the variability in numbers of flocks and of individuals. Waterfowl do show a diurnal pattern in that they usually feed by day and sleep at night (see Campbell 1978, Nilsson 1970, Dunthorne 1971).

Tidal influences.—Although use of tidal marshes and sloughs by waterfowl is frequently mentioned in the literature on geese on wintering grounds (Stewart 1962, Weller 1975, Daiber 1977, Fredrickson and Drobney 1979), there is little quantitative data examining the effects of tides on waterfowl. However, for Common Eiders (*Somateria mollissima*) tide has been considered the dominant factor influencing numbers and distribution (Gorman 1970, Pounder 1971, Milne 1974). Campbell (1978) found that tidal factors determined where the eiders concentrated to feed, and that the largest numbers concentrated in tidal areas when the tide was low.

In the present study Brant showed a strong response to tides, concentrating on the bay as the tide dropped and at low tide. Canada Geese were less influenced by tide levels. We attribute these differences to differences in foraging behavior: Brant feed on aquatic plants while Canada Geese feed on terrestrial plants (see Weller 1975). Presumably if Brant can feed optimally at low tide, they would begin to concentrate in foraging areas as the water levels drop. In contrast, Canada Geese feeding on land are independent of tide.

Weather influences.—Despite references to the effects of weather on waterfowl (Fredrickson and Drobney 1979), few quantitative data of its effects, except for temperature, are available. However, our study provided an opportunity to examine the effects of weather by comparing how Canada Geese and Brant used the different census areas.

Both Brant and Canada Geese used the ponds more than the bay when temperatures were high, and they used the bay more than the ponds when temperatures were low. Neither species used the ponds when they were partially or completely frozen, but instead concentrated elsewhere on the refuge where water remained open and food available.

Wind also influenced the distribution and abundance of birds. During strong winds Brant and Canada Geese usually remained on the lee side of salt marsh islands, or rafted behind tall phragmites. Canada Geese were absent from the bay in the highest winds, and remained in the ponds which were protected from winds by tall phragmites. Brant were also present on the ponds during very strong winds.

As cloud cover increased so did numbers of flocks and individuals of both species. We are unable to account for the significant relationship between the increase in geese numbers and cloud cover, unless reduced light concentrated birds as some sort of defensive response. Furthermore, for Brant that feed in the water, foraging conditions might be better under cloudy skies where bright sunlight does not reflect from the water's surface. Bovino and Burtt (1979) first suggested this explanation for decreased success under sunny skies for Great Blue Herons (*Ardea herodias*). The results of this study suggest that the effect of cloud cover on Canada Geese and Brant require further study.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This study indicates that spatial, temporal, tidal, and weather conditions all contributed to the variability in the abundance and local distribution of Canada Geese and Brant at an east coast estuary. Brant, but not Canada Geese were influenced by tidal factors, and they concentrated on the tidal bay on a falling tide, and at low tide. Brant used the tidal areas extensively, while Canada Geese primarily used the freshwater ponds. The increase in Canada Geese in late summer must represent post-breeding adults and young Canada Geese and these birds used only the ponds, moving into East Pond when the water levels were lowered by refuge personnel. Both species used the census areas differently under different environmental conditions. The availability of a wide diversity of habitats provided adequate areas for use under a variety of environmental conditions. The two species could minimize the effects of low temperatures and strong winds by shifting habitats. This study suggests that it may be important to maintain a diversity of habitats in any refuge to allow waterfowl to compensate for changes in weather. The man-made freshwater ponds were extensively used by Canada Geese, suggesting that the creation of similar freshwater ponds elsewhere on the east coast might aid this species.

SUMMARY

Numbers and movements of Brant (*Branta bernicla*) and Canada Geese (*B. canadensis*) were studied at Jamaica Bay Wildlife Refuge between 1 May 1978 and 1 May 1979. Jamaica Bay contains a variety of tidal habitats as well as two large freshwater ponds. Brant primarily used the tidal bay while Canada Geese were concentrated around freshwater ponds. Multiple regression analysis indicated that temporal and weather-related factors influenced the number of flocks and individuals of Canada Geese, while temporal, tidal and weather factors influenced Brant. The largest numbers of Brant and their flocks were present on the bay on falling tides and at low tides. The paper discusses the effect of temporal, tidal, and weather-related factors on the abundance and distribution of Brant and Canada Geese at Jamaica Bay Wildlife Refuge, and concludes that geese will use a diversity of habitats during different environmental conditions.

ACKNOWLEDGMENTS

We thank M. Gochfeld and L. Fredrickson for discussions on the research. Funding was provided by contract No. CX 1600-8-007 from the National Park Service. We thank P. A. Buckley (Chief Scientist) for his advice, support, and encouragement throughout this study.

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